4 inches, one telescope of 6 inch aperture, and a photographic instrument. These latter are being made by Dallmeyer in London, nearly after the pattern of the Kew-heliograph.

I shall be much interested to hear about Lord Lindsay's intentions through the promised paper at the Royal Astronomical Society.

On the Origin of the November Meteors.
By Richard A. Proctor, B.A. (Cambridge.)

Although the researches of Schiaparelli, Adams, Leverrier, and others, have demonstrated the nature of the orbit of the November meteors, and the existence of an association of some sort between these bodies and Tempel's comet (Comet I, 1866), yet the manner in which these and other meteors have entered our system remains as yet unexplained. Schiaparelli's theory on this point does not stand by any means in the same position as his theory respecting the association between meteor-systems and comets. Indeed it is impossible to consider carefully all the circumstances known respecting meteors on the one hand and respecting the interstellar regions on the other, without recognising very grave difficulties in the views of Schiaparelli.*

I wish to invite attention here, however, to those difficulties only which surround the theory that the November meteors entered the solar system from the interstellar spaces, and were forced to take up their present orbit by the attraction of the planet *Uranus*. It is known that this theory has been adopted, or at least supported, by no less an authority than Leverrier; and this might appear at a first view to render further inquiry superfluous, since no one will suppose that any considerations bearing on the dynamical relations of the question could be overlooked by Leverrier. But as a matter of fact the support of Leverrier has been accorded only to the general theory that a body arriving from interstellar space might be forced by the attraction of *Uranus* to take up an orbit like that of the November meteors. Leverrier has also shown that without any extravagant suppositions as to errors in the observations of the November meteors and Tempel's Comet, the comet might, in the year 126 A.D., have been near enough to *Uranus* to have its orbit changed to its present form. Against these propositions I have nothing to urge; but I wish to invite attention to the inquiry whether the event admitted to be possible in this case be not so highly improbable as to suggest that some other explanation of the circumstances should be looked for.

Considering the case of a single body—as a single particle—

* The association which he traces between nebulæ and comets must, in particular, be regarded as open to strong objections, whether we consider the spectroscopic evidence or the evidence which we have respecting the enormous distances of all the known nebulæ.

arriving from interstellar space (on a path inclined to the fixed plane of the solar system), and eventually, owing to the attraction of *Uranus*, forced to follow the path of Tempel's Comet, we have the following change in the body's circumstances to account for:—

Whereas arriving from outer space under the Sun's attraction such a body would cross the orbit of *Uranus* with a velocity of about 6 miles per second, in its new path it has at the same distance a velocity of about $1\frac{1}{2}$ miles per second. The action of *Uranus* must have been so exerted as to deprive the body of a velocity of about $4\frac{1}{2}$ miles per second.

Now *Uranus* acting alone on a body in the interplanetary spaces, and drawing that body to his surface, would impart to the body a velocity of about 13·7 miles per second. Such a body when at the distance of *Uranus's* nearest satellite (about 86,000 miles) would have acquired a velocity of about $4\frac{1}{2}$ miles per second. And since the velocity which a body can impart corresponds to the velocity which it can take away, it follows that *Uranus* could deprive a body of a velocity of $4\frac{1}{2}$ miles per second, supposing the body to start with such a velocity from the distance of the nearest satellite.

But it need hardly be said that under the actual circumstances in which the solar system exists, *Uranus* could not even impart or take away such a velocity as this from a body starting from the distance of the nearest satellite or approaching *Uranus* within that distance. In particular it is manifest that a body arriving from outer space under the Sun's attraction, and passing *Uranus* at the distance of the nearest satellite, would by its own motion, augmented by the effects of the Sun's attraction, be carried away from the influence of *Uranus* at such a rate that that influence, though tending to reduce the body's velocity (that is, under the actual circumstances preventing the velocity from increasing so fast as it otherwise would), would nevertheless not produce a total reduction of $4\frac{1}{2}$ miles per second. For such a change to be produced the body must pass much nearer to *Uranus*.

A fortiori, therefore, it follows that a body passing *Uranus* with a velocity of 6 miles per second must approach the planet much more nearly than its nearest satellite. And the inference is yet further strengthened by the consideration that as the body approached *Uranus* the planet's attraction would tend to increase the velocity of the body; it would only be the excess of the retarding action (owing to the relative motions of *Uranus* and the body) which would avail to reduce the body's motion on the whole.

The conclusion is, that such a body must pass very close indeed to *Uranus* to receive the requisite degree of retardation. We need not enter into numerical calculations, because in our ignorance of the actual circumstances under which according to the theory, the members of the meteor system approached *Uranus*, calculation would be more laborious than profitable. But it can

readily be shown that to produce the retardation required, *Uranus* must have been within 30,000 miles of a body arriving from interstellar space, and eventually travelling in such an orbit as that of the November meteors.

Even, however, if we only assume that a body must have passed within 80,000 miles of *Uranus* to receive the requisite retardation, we at once recognise several serious difficulties.

In the first place, the antecedent improbability of so close an approach, in the case of a body arriving from interstellar space, after a journey lasting several millions of years, is so enormous that we might on that account alone object to the theory that such an approach has in reality taken place. To give anything like a reasonable chance of such an approach in any single case the total number of meteor systems thus arriving from without should exceed incalculably even the enormous number of such systems which we begin to recognise as actually existing within the solar scheme.

But this is not all. We know that at present the November meteor system,—counting only those members which travel nearly enough to the orbit of Tempel's Comet to come under the reasoning here employed,—has an extension measured by millions of miles in breadth and depth, and by hundreds of millions of miles in length. It seems impossible to explain how all these bodies can once have been gathered within so small a space that the whole system was set travelling on its present orbit by the disturbing influence of *Uranus*. If ever so compact, the system should have been able by the mutual attraction of its members to maintain its compactness for a very long time—at least not be scattered over a space hundreds of millions of miles long, within the astronomically short interval of seventeen centuries.

One is thus led to doubt whether the November meteors have had an extra-planetary origin at all. They must once have been, all in a compact body, so near to *Uranus*, that the idea is suggested that they came *from Uranus;* that in fact he expelled them in some tremendous volcanic outburst. Strange as this may sound, it is after all not a whit more strange than the theory (which seems forced upon us by other evidence) that meteoric bodies have in some instances been expelled from our Sun or from his fellow-suns the stars. If we suppose that at any former epoch *Uranus* was in a sunlike state, it would have required no greater proportional expenditure of power in that small sun to expel meteoric matter than for the central Sun to overcome by his explosive energy the might of his own gravity. *Uranus* would have had to impart but a velocity of 13·7 miles per second to expel matter from him for ever—even if we leave out of account the way in which the Sun's action would help in bearing away matter once carried to a certain distance from *Uranus*.

Of course, similar considerations can be extended to all the planets, minor as well as major—nay, they could be extended even to the secondary planets.

It would be a natural consequence of such explosive actions as have here been suggested, that each of the greater planets would have a dependent family of meteor systems, or comets, revolving in orbits approaching very near to the orbits of their respective parent planets. We might not, or rather we certainly should not, be able to detect from the Earth one in many hundreds of these dependent comets; and if any were detected, the just inference would be that an enormous number of such comets existed. I need hardly remind those who will read these lines that many comets depending in just such a manner on the planet *Jupiter* have been already detected; that the case is the same with *Neptune;* that there is one comet at least, which on this view of the matter must be regarded as Saturnian; and that of course the system of bodies I am considering would be regarded as a dependant of the planet *Uranus.*

A rather singular result would follow (as Professor Herschel has reminded me) from the theory here considered. Comets expelled from *Jupiter*, partaking of his rapid motion of advance would be found to travel for the most part in the same direction as the planet. Comets expelled from the much more slowly moving *Neptune* would be as likely to travel in either direction. This agrees with observation. All the comets whose aphelia lie near the orbit of *Jupiter* advance; a considerable number of those whose aphelia lie near the orbit of *Neptune* regrede.

Lastly, it is obvious that, according to this theory, one or other of the nodes of each of these comets should lie very close to the orbit of the planet from which the comet had been expelled. Now the nodes of all the Jovian and Neptunian comets, as well as of the Saturnian comet and Tempel's (the Uranian) comet, lie near to the orbits of their ruling planets. In the case of Encke's comet, whose aphelion is now far away from *Jupiter's* orbit, and gradually drawing inwards away from it, the further node is necessarily very far from the orbit of *Jupiter.* But this node lies as close to that orbit as is possible under the circumstances, being so near to the aphelion that one may say the line of nodes coincides with the line of apses.

On Two probable Early Appearances of the Comet of the November Meteors (1866, I. *Tempel.*) By Mr. Hind.

Some ten years since I calculated three or four orbits for the comet observed by the Chinese during the last week in October, 1366, somewhat varying in each case the interpretation of the path described in their annals, as it is presented by M. Edouard Biot in the appendix to the *Connaissance des Temps* for 1846. The orbits bore a sufficient general resemblance to indicate the possibility of arriving at a correct idea of the elements, though on one point in the interpretation there remained a doubt.